

## 1.0 INTRODUCTION

### Lessons Learned

Lessons learned that may apply to the requirements contained in this LIR are located at the following web sites:

<http://int.lanl.gov/safety/pressure/index.shtml>

[http://www.lanl.gov/projects/lessons\\_learned/network.html](http://www.lanl.gov/projects/lessons_learned/network.html)

## 1.1 Background

The hazards that pressurized systems present to employees, property, and the public must be considered when designing, installing, testing, using, inspecting and maintaining these systems. These hazards include explosions and blast, high-speed fragments, liquid jets, oxygen deficiency, toxin release, and extremes of temperature.

This document complements Laboratory Performance Requirement [LPR 402-00-00, "Worker Health and Safety," Appendix 18](#).

The requirements contained in this document shall be used in conjunction with [LIR 402-580-01 "Cryogenic Fluids or Cryogenics"](#), [LIR 300-00-01 "Safe Work Practices"](#), [LIR 401.10.01 "Stop Work and Restart"](#), [LIR 402-510-01 "Chemical Management"](#), [LIR 402-130-01 "Abnormal Events"](#), [LIR 402-550-01 "Explosives"](#), and the [LANL Laboratory Engineering Manual](#)

**Guidance Note:** Available for guidance are LIG [402-1200-01 "Compressed Gases"](#), [LIG 402-1200-03 "Gaseous and Liquid Hydrogen"](#) and [LIG 402-1200-02 "Inspection and Testing of Pressure Systems"](#).

The contents of this document shall become effective upon the issue date.

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## 1.3 Web Site

**Guidance Note:** The LANL pressure safety web site is at <http://int.lanl.gov/safety/pressure/index.shtml>.

## 2.0 PURPOSE

The purpose of the requirements contained in this LIR shall be to provide for the implementation expectations required for ensuring the safety of Laboratory pressure vessels, pressurized piping, vacuum systems, and cryogenic systems that could pressurize, to include both programmatic and many programmatic support and facility pressure systems. (Appendix 1 states the criteria for inclusion or exclusion.)

The purpose of this revision shall be to increase the clarity and user friendliness of the requirements contained in this LIR, and to assure that all hazardous and *potentially* hazardous pressure systems are included in these requirements.

## 3.0 SCOPE AND APPLICABILITY

All Laboratory organizations that are involved with pressure systems that are potentially hazardous (see App. 1) must implement the requirements contained in this LIR. These requirements shall apply to all Laboratory employees, affiliates, visitors, vendors, contractors, subcontractors, and their employees.

## 4.0 ACRONYMS AND DEFINITIONS

### 4.1 Acronyms

API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ANSI	American National Standards Institute
CGA	Compressed Gas Association
DL	division leader
DOE	US Department of Energy
DOT	US Department of Transportation
EDS	Employee Development System
HCP	hazard Control Plan
HSR	Health, Safety, and Radiology (Division)
FM	facility manager
GL	group leader
HCP	hazard control plan
HEPA	high-efficiency particulate air (filter)
LANL	Los Alamos National Laboratory
LIG	Laboratory implementation guidance
LIR	Laboratory implementation requirement
LPR	Laboratory performance requirement
MAWP	maximum allowable working pressure
MOP	maximum operating pressure
NBIC	National Board Inspection Code
NFPA	National Fire Protection Association
PM	program manager
PRD	pressure relief device
psia	pounds per square inch (absolute)
psig	pounds per square inch (gauge)
PSC	Pressure Safety Committee
R&D	Research and development
SRS	Savannah River Site
TNT	trinitrotoluene

### 4.2 Definitions

**allowable stress**—the maximum allowable stress in pressure vessel walls as specified by the appropriate design code (e.g., the ASME Boiler and Pressure Vessel Code) when the pressure system contents are at their MAWP.

**benign service**—Any pressure system that is sufficiently compatible with the materials of construction so that no component of the pressure system loses more than 0.001 in. of thickness per year of operation as the result of corrosion or erosion.

**compressed gas**—Gas stored and used at pressures greater than nominal atmospheric pressure (14.7 psia at sea level and 11.3 psia at 7200 ft in Los Alamos) that are normally supplied in cylinders, tube trailers, and through piping systems.

**corrosion allowance**—The thickness of material added by design to allow for material loss due to corrosion or erosion for the operating life of the vessel.

**corrosive service**—Any pressure service that, because of chemical or other interaction with the container's materials of construction, contents, or external environment, could cause the useful thickness of the pressure container to diminish, through any structural deterioration mechanism, by more than 0.001 in. per year.

**Cryogenic and Liquefied Gas Safety Committee (CLGSC)**—An independent peer review committee that provides advice regarding design and operation of cryogenic systems and safe use of cryogenic and liquefied gases.

**cryogenic fluid (cryogen)**—A liquid with a normal boiling point below approximately 120 K (-244 °F, -153 °C).

**cryogenic system**—A system operating at temperatures where cryogenic fluids could be condensed, or containing cryogenic liquids or solids.

**Dewar**—A thermally insulated, vented vessel designed to contain cryogenic liquids with low boil-off loss.

**explosive**—A metastable chemical that can suddenly decompose to produce shock waves, blast, and heat.

**facility pressure system**—Commercial pressure systems such as boilers, compressed air storage and water heaters used in support of buildings, machine shops and other Laboratory facilities.

**fault condition**—An abnormal operating condition where high pressure can be reached due to, for example, a chemical/explosive reaction, internal heating from radioactive decay, or an external heat source.

**hazard control measures**—Engineering design steps, administrative actions, ventilation, and personal protective equipment to mitigate workplace hazards.

**Hazard Control Plan (HCP)**—A document that defines the work, describes the proposed system, identifies the associated hazards, and states the controls to be implemented to reduce the hazards to the required level of safety.

**high-efficiency particulate air (HEPA) filter**—An air filter having at least 99.97% filtration efficiency.

**liquefied gas**—Gas that can be maintained in a pressure vessel in the liquid state at room temperature by elevating the pressure.

**Guidance Note:** The gas phase exists above the liquid phase, both saturated (a state where pressure and temperature are linked). Carbon dioxide cylinders and propane tanks are examples of pressure vessels containing liquefied gases.

**manned area**—A work area containing pressure systems that are pressurized when personnel are usually present.

**maximum allowable working pressure (MAWP)**—The maximum pressure at which a system is safe to operate based on the selected design code.

**Guidance Note:** The MAWP is the pressure that generates the maximum allowable stresses in the pressure vessel. It is also the *maximum* allowable set pressure for the primary pressure relief device (that set pressure can always be lower than the MAWP). The MAWP is based on end-of-life conditions. Credit is not taken for increased metal thickness for corrosion allowance.

**maximum operating pressure (MOP)**—The highest pressure allowed during normal operation, which is to be at least 10% below the MAWP, and preferably 20%.

**national codes and standards**—Documents published by nationally recognized organizations that give requirements based on the cumulative experience and engineering judgment. (ASME, API and DOT produce such codes.)

**normal operation**—Operation under routine conditions excluding a fault condition.

**pressure relief system**—A system designed to relieve excess internal pressure that includes pressure relief devices (relief valves and/or rupture disks), piping from the pressure vessel to the relief device, and piping from the relief device to the release point.

**pressure system**—A connected system consisting of pressure vessels; interconnecting hardware (including piping, tubing and fittings); instrumentation; and devices such as valves, pressure relief equipment, and flare systems.

**pressure vessel**—A container designed to hold pressurized fluids.

**Guidance Note:** Pressure vessels not meeting national codes and standards are “specialized pressure systems.”

**Pressure Safety Committee (PSC)**—A committee consisting of experts that review and approve pressure vessels and pressurized piping systems used at the Laboratory or in conjunction with Laboratory responsible operations.

**programmatic pressure systems**—Specially designed noncommercial pressure systems for Laboratory experiments and other R and D.

**programmatic support pressure systems**—Commercial pressure systems that support Laboratory experiments and other R and D. Examples are compressed gas supply systems and cryogenic dewars.

**remote area**—A work area containing pressure systems where personnel are prohibited when the pressure system is pressurized.

**safety factor**—The ratio of ultimate tensile strength to allowable stress.

**set pressure** - The pressure at which a pressure relief device begins to vent.

**specialized pressure system**—A pressure system that does not meet the requirements of national (industrial) codes and standards.

**stored energy**—A property of a system that is a function of pressure, the material pressurized (liquid or gas), and the volume of that material. It is proportional to the product of that pressure and volume.

**Guidance Note:** Stored energy may be expressed in units of foot-pounds, joules, or TNT equivalence (4.6 kJ/gm). A large-volume of low-pressure gas could have a significant amount of stored energy, as might one with high-pressure and low-volume. A pressurized liquid system can have a significant amount of elastic stored energy in the vessel itself as well as in the liquid. Stored energy criteria are given in Appendix 1.

**trapped volume**—A sealed region of a cryogenic system, typically between two valves, that can pressurize due to cryogen heating and subsequent vaporization.

**used vessel**—A vessel of unknown origin or a vessel proposed for use in applications other than those for which it was designed and certified.

**vacuum system**—A system normally operating at less than local ambient pressure

## 5.0 PRECAUTIONS AND LIMITATIONS

**Guidance Note:** The requirements contained in this document do not address all conceivable situations. Contact the Health, Safety and Radiology (HSR-5) Division representative (667-4644 or 665-6936) for any special situations or to address exceptions to the requirements found in this document.

## 6.0 IMPLEMENTATION REQUIREMENTS

### 6.1 Personnel and Organizational Responsibilities

Who	Shall
<b>Laboratory Associate Director for Operations</b>	<ul style="list-style-type: none"><li>authorize the Laboratory-wide Pressure Safety Program and the chartering of the Pressure Safety Committee.</li></ul>
<b>Division Leader</b>	<ul style="list-style-type: none"><li>ensure that every pressure system within their division is assigned to an owner who is responsible for its safe installation, use, maintenance, and periodic inspection.</li></ul>
<b>HSR Division Leader</b>	<ul style="list-style-type: none"><li>oversee the Pressure Safety Program and the activities of the Pressure Safety Committee.</li></ul>
<b>Facility Manager</b>	<ul style="list-style-type: none"><li>ensure the safe installation, use, maintenance, and periodic inspection of pressure systems that are used either as part of normal building services or for programmatic support.</li></ul>
<b>Group Leader</b>	<ul style="list-style-type: none"><li>ensure the required design, safe installation, use, maintenance, and periodic inspection of pressure systems that are used for programmatic and R&amp;D purposes.</li></ul>
<b>Both Facility Managers and Group Leaders</b>	<ul style="list-style-type: none"><li>ensure that all required documentation, reviews (including pressure safety review), and approvals are completed before permitting operation of their pressure systems.</li><li>ensure that only trained and qualified personnel perform pressure system</li></ul>

# Pressure, Vacuum, and Cryogenic Systems

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Los Alamos National Laboratory

Laboratory Implementation Requirements LIR 402-1200-01.1

Original Issue: October 1, 1999 Revised XXXXXXXX

Mandatory Document

	<p>design, fabrication, quality assurance and acceptance tests, and operations, inspections and maintenance.</p> <ul style="list-style-type: none"><li>• ensure that Laboratory worker training is documented and that the workers demonstrate competency for the work to be performed.</li><li>• shall immediately respond to and have corrected unsafe conditions in or near pressure systems.</li></ul>
<b>Who</b>	<b>Shall</b>
<b>Industrial Hygiene and Safety Group</b>	<ul style="list-style-type: none"><li>• upon request, provide toxicity and ventilation requirements when employing potentially hazardous gases and cryogens.</li><li>• upon request, assist in determining the hazards and required control measures for operation and testing of pressure, vacuum, and cryogenic systems.</li></ul>
<b>Pressure Safety Committee (PSC)</b>	<ul style="list-style-type: none"><li>• review the designs, hardware, and operating, testing and inspection procedures of pressure systems that fit the criteria shown in Appendix 1, or by request.</li><li>• review and approve deviations (variances or exceptions, see <a href="#">LIR 301-00-02</a>) from accepted pressure system standards and deviations from the requirements contained in this LIR.</li><li>• review and approve pressure systems that have been used before, or are of unknown design, and/or are proposed for use in applications other than for which they were intended.</li><li>• support the Laboratory in the area of pressure safety.</li><li>• report to the HSR-5 Division Leader and submit to him/her a fiscal year summary of all activities.</li><li>• Coordinate pressure safety issues with the Explosives, and Cryogenic and Liquefied Gas Safety Committees.</li><li>• Investigate pressure system failures, potentially hazardous leaks and other abnormalities relating to the safety of the system.</li><li>• be immediately notified in the event of a pressure system failure, potentially hazardous leak or other abnormality relating to the safety of the system.</li></ul> <p><b>Guidance Note:</b></p> <ul style="list-style-type: none"><li>• The PSC may be contacted by calling the HSR-5 Operational Safety Section (665-6936 or 667-4644).</li><li>• Members of the PSC can assist in the design and inspection of pressure systems and review operating procedures. It is recommended that the PSC be involved as early as possible.</li></ul>
<b>Cryogenic and Liquefied Gas Safety Committee</b>	<ul style="list-style-type: none"><li>• provide guidance and participate in reviewing cryogenic pressure systems when requested by the Pressure Safety Committee.</li></ul>
<b>Pressure System Operating Personnel</b>	<ul style="list-style-type: none"><li>• operate and maintain pressure systems only when authorized.</li><li>• complete and document completion of the pressure, gas cylinder, and cryogen training courses required for their work with pressure systems.</li><li>• ensure that the pressure system requirements contained in this LIR, <a href="#">Laboratory Safe Work Practices (LIR 300-00-01)</a>, and the requirements stated in facility or project-specific procedures, are implemented.</li><li>• ensure that other personnel working with or near them, or under their supervision, implement the requirements contained in this LIR.</li><li>• immediately report pressure system accidents, near-accidents, and unusual occurrences to their immediate supervisor.</li></ul>

	<ul style="list-style-type: none"> <li>maintain and provide upon request by the PSC the records required as stated in this LIR.</li> </ul>
<b>Who</b>	<b>Shall</b>
<b>Pressure System Designers and Reviewers</b>	be properly trained, qualified, and experienced by means of: <ul style="list-style-type: none"> <li>training, education, and experience with pressure systems,</li> <li>working knowledge of required codes and standards,</li> <li>a working knowledge of the analyses, materials and fabrication methods used in pressure systems, and</li> <li>a working knowledge of pressure system maintenance and inspection.</li> </ul>
<b>All Personnel</b>	immediately stop work, require others to leave the area, and notify the PSC and their immediate supervisor if an unsafe condition appears to exist in or near a pressure system.

## 6.2 Implementation Requirements for Pressure Systems

Activity	Requirements
<b>Pressure System Design</b>	<p><b>1. Pressure Vessels:</b></p> <ul style="list-style-type: none"> <li>Pressure vessel design must include sound engineering practices and judgment. In addition, the following national design codes shall be used whenever possible. Deviations from these codes shall require approval of the Pressure Safety Committee.</li> </ul> <p><i>For pressure vessel designs with contents below 3000 psi, one of the following codes shall be implemented:</i></p> <p>ASME Boiler and Pressure Vessel Code Section VIII Div. 1 or 2 ASME Boiler and Pressure Vessel Code Section III Div. 1</p> <p><i>For pressure vessel designs above 3000 psi, use the following code:</i></p> <p>ASME Boiler and Pressure Vessel Code Section VIII Div. 3.</p> <p><b>Guidance Note:</b> The PSC can assist in the application of the above Codes.</p> <ul style="list-style-type: none"> <li>Design pressures (i.e., MAWP) must include potential fault pressures (e.g., from an unexpected exothermic reaction of the contents) as well as normal operating pressures. Therefore, sealed systems normally not pressurized may still be required to meet the requirements contained in this LIR. See Appendix 1.</li> </ul> <p><b>Guidance Note:</b> Care should be taken in the proper design of the pressure vessel shipping container as well as the vessel itself.</p> <p><b>2. Piping:</b></p> <p>Piping within pressure systems shall be reviewed by the PSC. Emphasis shall be placed on allowable pressures, required securing, location of pressure relief devices, and consequences of inadvertent or incorrect valve operation.</p> <p><i>For pressure piping designs, use the following codes and standards:</i></p> <p>ASME Process Piping Code B31.3 ASME Piping Pressure Ratings and Standards B16 (Use the appropriate subsection).</p>

	<p>Vent valves that are normally closed shall be capped off (finger-tight is acceptable).</p> <p><b>3. Pressure Relief Devices:</b></p> <ul style="list-style-type: none"><li>• Each part of any pressure system that can be pressurized separately shall be protected by a pressure-relief device (PRD) with a set pressure at the local MAWP or less.</li><li>• The PRD chosen shall be consistent with the contents of the pressure system.</li><li>• Valved-off vacuum systems used to purge pressure systems shall have their own pressure relief device to protect the vacuum system against a valve being accidentally left open.</li><li>• The PSC must approve each system where pressure relief devices are not used (e.g., with radioactive gases or toxins).</li></ul> <p><b>Guidance Note:</b> Safety factors are generally doubled when there are no pressure relief devices.</p> <ul style="list-style-type: none"><li>• If a valve is placed between the protected pressurized volume and the PRD, it must be lock-wired open during normal operation.</li><li>• No obstruction shall impede the function of PRDs.</li><li>• Rupture discs must not be blocked or painted, nor shall tamper-indicating devices be blocked or painted.</li><li>• Relief devices must be tagged to indicate the set pressure and date of last inspection.</li></ul> <p>• <i>For pressure relief device selection and design, the following codes shall be implemented:</i> ASME Boiler and Pressure Vessel Code Section VIII, Div. 1, Part UG, Par. 125-134. ASME Boiler and Pressure Vessel Code Section VIII, Div. 2, Part AR. API 520 and 521.</p> <ul style="list-style-type: none"><li>• PRD vent lines must be directed away from personnel.</li><li>• Flammable gas PRD vents shall be directed outside if possible, or at least above head level.</li><li>• PRD flow areas shall be at least 1.5 times the flow area immediately upstream.</li><li>• PRD vent line flow areas shall be equal to or greater than the PRD flow area.</li></ul> <p><b>Guidance Note:</b> Commercial pressure systems frequently have inadequate pressure relief devices.</p> <p><b>Guidance Note:</b> Venting into a T-fitting will cancel reaction forces.</p> <p><b>4. Brittle Components:</b></p> <ul style="list-style-type: none"><li>• Many pressure systems at the Lab have glass viewports and other brittle components such as ceramics must provide shielding so that failure does not injure personnel.</li></ul>
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	<ul style="list-style-type: none"> <li>A safety factor of at least 4, based on the minimum material tensile strength, shall be applied to brittle components.</li> </ul> <p><b>Guidance Note:</b> The PSC may require that this be raised to as high as 8.</p> <p><b>Guidance Note:</b> Care will be taken to avoid stress concentrations in brittle materials, especially at points of contact with other components.</p>
<b>New Commercial and Used Pressure Systems</b>	<p><b>New Commercial Systems:</b> Contracts for purchasing pressurized vessels and, in some cases, entire pressure systems designed and fabricated outside the Laboratory must specify either of the following:</p> <ul style="list-style-type: none"> <li>that design drawings and calculations, materials, fabrication methods, and pressure tests and QA are approved and certified by a professional engineer that the required codes specified above have been satisfied, or</li> <li>that the pressure vessels that received an NBIC inspection and an ASME Code stamp.</li> </ul> <p>PSC review shall not be required if either of the above conditions are met. However, if there is no PE certification or Code stamp, then the following documentation must be supplied to the PSC for review:</p> <ul style="list-style-type: none"> <li>Design and structural analysis,</li> <li>Post weld heat treatment (if any),</li> <li>Welding methods used including weld rod material,</li> <li>Quality assurance procedures including material certification, and</li> <li>Pressure test results</li> </ul> <p>Specialized pressure systems, such as piping assemblies, to which commercial pressure vessels are attached shall require PSC review.</p> <p><b>Used, Modified or Surplus Systems:</b> Before any used or modified surplus vessels or systems are used, as much of the following information as possible shall be provided to the Pressure Safety Committee to determine the vessels' suitability for service:</p> <ul style="list-style-type: none"> <li>name of manufacturer and date of construction,</li> <li>original hydrostatic (or pneumatic) test pressure and date,</li> <li>ASME stamping and/or registration number,</li> <li>National Board Inspector's Code number,</li> <li>materials of construction,</li> <li>original design pressure and temperature,</li> <li>detailed drawings,</li> <li>pressure-relieving devices and relief pressures,</li> <li>type and history of previous service (i.e., cyclic pressure and temperature, corrosive contents),</li> <li>description of any repairs or modifications, and</li> <li>engineering calculations supporting the original design and any modifications.</li> </ul> <p>Prior to use of the above pressure system, the user shall</p> <ul style="list-style-type: none"> <li>perform a visual examination of the vessel for obvious defects,</li> <li>determine how much useful wall thickness remains (e.g., with ultrasound),</li> <li>perform a dye-penetrant inspection of critical welds,</li> </ul>

	<ul style="list-style-type: none"> <li>perform reverse engineering stress calculations if none are available, and</li> <li>perform hydrostatic or pneumatic tests in accordance with the required Code.</li> </ul>
<b>Pressure Systems Using Compressed Gas Cylinders</b>	<ul style="list-style-type: none"> <li>Closed, or potentially-closed, pressure systems connected to compressed gas cylinders must implement the requirements contained in this LIR.</li> <li>The system pressure and stored energy are taken to be that of the closed system downstream of the regulator at the system MAWP.</li> <li>This MAWP shall be that of the weakest part of the closed pressure system. If the MAWP is less than the maximum pressure in the gas cylinder, a pressure relief device shall be installed immediately downstream of the gas cylinder regulator set to the system MAWP (or less).</li> <li>Safety manifolds (see <b>LA-UR-01-5176 "Pressure Safety Orientation"</b>) shall be implemented on all closed systems attached to a gas cylinder that could overpressurize if the regulator failed.</li> <li>Open flow systems connected to gas bottle supplies, where the pressure downstream of the regulator never exceeds 15 psig, shall have a pressure relief device with a set pressure of 15 psig or less immediately downstream of the regulator.</li> <li>In such open systems, components downstream of the relief device shall not be required to implement the requirements contained in this LIR.</li> </ul> <p><b>Guidance Note:</b> The required handling and storage of gas cylinders is discussed in detail in <a href="#">LIG 402-1200-01.0 "Compressed Gases"</a> and in <a href="#">LA-UR-00-1483 "Gas Cylinder Safety"</a>.</p> <ul style="list-style-type: none"> <li>In general, cylinders must be inspected prior to use, inventories must be minimized, and cylinders must be safely stored (with caps on) to prevent, for example, impact, falling, or rolling.</li> <li>Unused cylinders shall be returned to the Gas Plant.</li> <li>Personnel working with gas cylinders must complete the Gas Cylinder Safety Training course 9518 offered by PS-13.</li> </ul>
<b>Vacuum Systems</b>	<p><b>Vacuum Only Systems:</b></p> <ul style="list-style-type: none"> <li>Vacuum vessels shall be designed using the same codes as pressure vessels and shall also include an analysis of buckling stability.</li> <li>Vacuum vessels over 285 liters (10 ft<sup>3</sup>) shall be subject to the requirements contained in this LIR (see Appendix 1 for reason).</li> </ul> <p><b>Positive and Negative Pressure Systems:</b></p> <ul style="list-style-type: none"> <li>Vacuum systems intended for both vacuum and positive internal pressure and with stored energy greater than that shown in Appendix 1 based on MAWP, and positive pressure greater than 15 psig, shall be considered a pressure vessel and the requirements contained in this LIR must be implemented.</li> </ul> <p><b>Viewports:</b></p> <ul style="list-style-type: none"> <li>Non-commercial viewports in a vacuum system, including those made of quartz and sapphire, and are greater than 2-in. in diameter, shall be subject to a pressure safety review.</li> </ul> <p><b>Pressure Relief Devices:</b></p> <ul style="list-style-type: none"> <li>Relief devices on vacuum systems shall not be required if a documented</li> </ul>

	<p>analysis positively identifies that it is impossible to pressurize a system to over 15 psig by any reasonable scenario without consideration for any pressure relief devices, otherwise, pressure relief devices shall be required.</p> <p><b>Guidance Note:</b> Commercial vacuum pump requirements are not covered by this document.</p>
<b>Cryogenic Systems</b>	<p><b>Cryogenic Pressure Vessel Design:</b></p> <ul style="list-style-type: none"> <li>• Cryogenic pressure vessels shall be designed with the ASME Codes using potential fault pressures (such as from cryogen boiloff) as the MAWP.</li> <li>• Attention must be applied to selecting the choice of materials to avoid cold embrittlement and stresses from differential thermal contraction (including those from rigid supports).</li> </ul> <p><b>Pressure Relief Devices:</b></p> <ul style="list-style-type: none"> <li>• Pressure relief devices shall be installed in every space where liquid cryogen or cold gas could be trapped, typically between two valves, or where ice buildup can cause blockage and consequent pressurization.</li> <li>• A pressure relief device shall also connect to the insulating vacuum space of cryostats containing a cryogen that may leak into that vacuum and pressurize it.</li> <li>• Relief devices must be designed for cryogenic service if required.</li> </ul> <p><b>Piping:</b></p> <ul style="list-style-type: none"> <li>• The cryogenic piping selected must permit thermal contraction and condensation.</li> </ul> <p><b>Dewars:</b></p> <ul style="list-style-type: none"> <li>• Dewar owners shall ensure that water or air ice plugging does not occur.</li> <li>• If an ice plug does occur, a trained two-man team shall attempt to unplug it with a warm copper rod or tube, if that activity can be performed safely.</li> <li>• If the Dewar cannot be unplugged safely, EM&amp;R shall be called to dispose of it.</li> <li>• Required procedures shall always be implemented to ensure minimization of the risk of such plugging.</li> </ul> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><b>Guidance Note:</b> Vented boiloff from liquid nitrogen and helium Dewars will preferentially condense oxygen out of the air, possibly creating a fire hazard. Liquid nitrogen passing through poorly insulated pipes may do the same on the pipe exterior until an ice layer forms.</p> </div> <p>Appendix 1 states the requirements by which cryogenic systems must be treated as pressure systems subject to the requirements contained in this LIR.</p> <p><b>Guidance Note:</b> Additional requirements for mitigating the hazards of cryogens are addressed in <a href="#">LIR 402-580-01, "Cryogenic Fluids or Cryogens."</a></p>

### 6.3 Implementation Requirements for Pressure System Testing, Inspection, and Operation

<b>Pressure System Testing and Inspection</b>	<p><b>Installed New Pressure System Pressure Tests</b></p> <ul style="list-style-type: none"> <li>• A pressure and leak test shall be required on the complete assembled pressure system prior to operation.</li> <li>• If pressure relief valves are in use, the test pressure shall be that which lifts the relief valve.</li> <li>• If burst discs are in use, the test pressure shall be 90% of the burst disc set pressure.</li> <li>• The PSC shall witness the pressure test unless a variance has been formally approved by the PSC.</li> </ul> <p><b>Guidance Note:</b> The pressure tests can be either pneumatic or hydraulic.</p> <p><b>Existing Pressure System Pressure Tests</b></p> <ul style="list-style-type: none"> <li>• Existing pressure systems that have been in service shall, at the discretion of the PSC, be required to undergo non-destructive inspections to determine remaining wall thicknesses and corrosion rates, weld integrity, and other <i>fitness-for-service</i> evaluations that could include pressure tests.</li> <li>• <i>For pressure vessel and piping pressure testing procedures, the following code requirements shall be implemented as required:</i> ASME Boiler and Pressure Vessel Code Section VIII, Div. 1, Part UG, Par. 99-100. ASME Boiler and Pressure Vessel Code Section VIII, Div. 2, Articles T-3 and T-4. ASME Boiler and Pressure Vessel Code Section III, Div. 1, Subsection NB, Article NB-6000.</li> </ul> <p><b>Inspections:</b></p> <ul style="list-style-type: none"> <li>• All operational pressure systems subject to the requirements contained in this LIR shall have a formally stated maintenance regimen that includes periodic inspection of all pressurized components in the system.</li> <li>• Pressure systems with no documented history of inspections shall require a <i>fitness-for service</i> evaluation unless a variance has been approved by the PSC.</li> <li>• Follow-on inspection frequencies shall be based on a combination of <i>risk-based inspection</i> methodology (see below) and good engineering judgment.</li> <li>• Pressure system inspections shall be conducted by API or NBIC qualified inspectors unless a variance has been approved by the PSC to authorize them to be conducted by other knowledgeable personnel.</li> <li>• <i>For pressure system inspection procedures, the following code requirements shall be implemented as required:</i> Fitness-for-service: API 579 Risk-based inspection: API 580, 581 Pressure vessel inspection: API 510, 572, 573 Piping, valves, and fittings: API 574 Pressure relief devices: API 576</li> </ul>
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	<p><b>Guidance Note:</b> See Appendix 3 for a listing of maximum allowable inspection and replacement intervals.</p> <ul style="list-style-type: none"> <li>• Inspection dates and pressure test results shall be durably marked on the pressure system component.</li> <li>• Documentation of pressure test and inspection results shall be retained for the life of the system by the pressure system owner and Facility Manager or their designee.</li> </ul> <p><b>Guidance Note:</b> The MAWP shall be marked on the fitting that the PRD attaches to in order to ensure the correct PRD is replaced after removal for inspection or replacement.</p>
<b>Pressure System Operation</b>	<p><b>Evaluation Before Operation:</b></p> <ul style="list-style-type: none"> <li>• Before initial operation of a new or modified pressure system, the responsible group leader or designee of the owning organization shall ensure that all safety concerns have been resolved and that the requirements contained in this LIR have been implemented or that deviations from these requirements have been formally approved by the PSC.</li> </ul> <p><b>Labeling and Marking:</b></p> <ul style="list-style-type: none"> <li>• Pressure systems shall be legibly and durably marked with labels that identify the MOP, MAWP, temperature range, flow directions, and contents.</li> <li>• A detailed schematic posted nearby the system shall satisfy this requirement provided the actual components shown on the schematic are readily identifiable.</li> </ul> <p><b>Maintenance and Repair:</b></p> <ul style="list-style-type: none"> <li>• No maintenance or repair work on a pressure system shall be performed while it is under pressure. The requirements contained in <a href="#">LIR 402-860-01, "Lockout/Tagout for Personnel Safety"</a> must be implemented.</li> <li>• During manned entry of large vessels, highly visible signs shall be posted indicating that personnel are inside.</li> <li>• A vent valve shall remain open until an access port to the interior of the vessel is opened (see <a href="#">LIR 402-810-01.0 "Confined Spaces"</a> for more information).</li> <li>• The PSC shall be notified of any upcoming pressure system repair or modification that could affect pressure-bearing components.</li> </ul> <p><b>Guidance Note:</b> The Committee, at its discretion, may require a pressure safety review prior to, and/or after, the work being performed.</p> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <p><b>Guidance Note:</b> Many pressure system incidents have occurred during maintenance or modification when, for some reason, safety procedures tend to be ignored.</p> </div> <p><b>Radioactive Contents:</b></p> <ul style="list-style-type: none"> <li>• To prevent cross-contamination when supplying compressed gas to pressure systems with radioactive contents, the following special precautions shall be implemented:</li> </ul>

	<ul style="list-style-type: none"> <li>– Remove gas cylinders from service when cylinder pressure drops below 40 psig, rather than the customary 25 psig.</li> <li>– Install an in-line HEPA filter between the compressed gas supply and the potentially-contaminated system. This step is not necessary for tritium-contaminated systems because it is ineffective.</li> <li>– Before a potentially-contaminated cylinder is removed, contact the local RCT to monitor for contamination.</li> <li>– Whenever possible, use check valves to prevent backflow contamination.</li> </ul>
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## 7.0 DOCUMENT RESPONSIBILITY

Each pressure system owner shall be responsible for

- maintaining design drawings, specifications, quality assurance and review documentation, and pressure test results
- maintaining an inventory of all pressure and cryogenic systems under their control, as well as an inventory of vacuum systems that qualify as pressure systems
- maintaining inspection, testing, and maintenance documentation for the life of the system, and
- upon request, supply copies of the above documentation to the Pressure Safety Committee.

The Health, Safety, and Radiology Group, HSR-5, shall be responsible for the contents of this document.

## 8.0 APPENDICES (1-3 are mandatory)

1. Guides for Inclusion and Exclusion of Pressure Systems Into This LIR
2. Flammable Pressurized Gases
3. Maximum Pressure System Inspection Intervals
4. Pressure Safety Committee Reviews
5. List Of Possible Pressure System Failure Modes
6. Pressure Safety Walkaround Checklist For Existing Programmatic Systems
7. Useful References

## APPENDIX 1 (Mandatory)

### REQUIREMENTS FOR INCLUSION AND EXCLUSION OF PRESSURE SYSTEMS INTO THIS LIR

**Background:** Section 1 states the general requirements for pressure systems that must be included into the requirements contained in this LIR. Section 2 below provides the detailed requirements that must be implemented. Section 3 provides the methods that must be implemented to determine stored energy. Section 4 lists those pressure systems that shall be excluded from the requirements contained in this LIR.

**Guidance Note:** The criteria below may seem complex; but this is necessary to assure that hazardous pressure systems are included while, at the same time, unimportant systems are not. Contact the PSC (665-6936) for help if needed. Even if a system falls outside of the requirements below, PSC review, even a brief one, is still recommended and can add value to the project.

#### 1. GENERAL INCLUSION REQUIREMENTS

##### a. New vs. Existing Pressure Systems

The requirements contained in this LIR includes some pressure systems that were previously excluded and vice-versa; therefore, to facilitate the transition of these systems, the following shall be implemented;

- All newly-designed pressure systems, not yet in the fabrication stage, that exceed the pressure and stored energy criteria below, shall be subject to the design and review requirements contained in this LIR.
- Pressure systems that have begun or completed fabrication as of the issue date of this LIR, that were excluded before but are included now, shall again be excluded.
- Pressure systems that have begun or completed fabrication as of the issue date of this LIR, that met the requirements contained in the previous LIR version shall remain governed by the requirements contained in that version.
- All of the above pressure systems shall remain subject to the maintenance and inspection requirements contained in this LIR.

##### b. Basis for Stored Energy Threshold

- The stored energy threshold shall be based on blast injury from an equivalent amount of TNT at a specified range.
- The blast injury chosen shall be the incipient ear damage, which occurs at a blast pressure of about 5 psig for a wide range of blast pulse durations. However, inside a building wall reflections can double this pressure, lowering the allowable incident pressure to 2.5 psig.
- A factor of three safety factor shall then be applied, lowering the allowable incident pressure to 0.7 psig.
- The range chosen shall be 10 feet from the source.

**Guidance Note:** It can be shown that 5.9 grams of TNT on the ground will produce an open air blast pressure of about 0.7 psig at 10 feet. This amount of TNT corresponds to 27 kJ. This has been rounded down to 20 kJ.

- A value of **20 kJ** shall be the stored energy criterion **for normal operation**.

- For pressure systems located in closed rooms, the room volume must at be a **minimum of 30 cubic feet per kilojoule of stored energy** to limit pressurization of the room during a sudden venting or failure of the pressure system.

**Guidance Note:** The PSC may require more volume if the room is tightly sealed or if room pressurization could present special hazards.

- For some **fault conditions** (see next section) in a normally unpressurized system, the stored energy criterion shall be **100 kJ** (see below) and there shall be no requirement for room volume.

## 2. DETAILED INCLUSION REQUIREMENTS

- a. Pressurized systems, where personnel could be exposed to injury if the system fails, shall be required to implement the requirements contained in this LIR and require Pressure Safety Committee review under any of the following conditions (stored energy is for the entire connected system):

1. **Non-hazardous** gas contents and **usually pressurized**, and vacuum systems:  
P > 15 psig (11.3 psia external for vacuum systems), stored energy > 20 kJ at MAWP.  
To determine stored energy, see **3a** below.
  2. **Non-hazardous** gas contents, usually under 15 psig but **could possibly be nonviolently pressurized** to over 15 psig (for example, over time by a heat source):  
Stored energy > 100 kJ at 15 psig.  
To determine stored energy, see **3a** below.
  3. Contents in any form that are **potentially explosive, or can catalytically/chemically react violently, or are toxic/flammable/radioactive**:  
All such systems normally operating above 15 psig, or are usually unpressurized *but could potentially pressurize during a fault condition to above 15 psig*, would be subject to this LIR and PSC review regardless of stored energy.
  4. **Non-hazardous pressurized liquid** contents with no cover gas (i.e., a sealed gas volume over the liquid):  
P > 300 psig, stored energy (including container walls) > 20 kJ at MAWP.  
To determine stored energy, see **3c** below.
  5. **Non-hazardous pressurized liquid contents with non-hazardous cover gas** (including partially filled or two-phase):
    - a. For different gas than liquid: Use 1 above based on gas only, or 4 above, whichever is the more conservative.
    - b. For two-phase (same gas as liquid): P > 150 psig, stored energy > 100 kJ at MAWP (both at 70°F) based on isentropic expansion to one atmosphere at LANL.  
To determine stored energy for b, see **3b** below.
  6. **Non-hazardous (excluding oxygen deficiency hazard) cryogenic liquid/solid** contents in **non-commercial** pressurizeable containers:  
All such containers shall be subject to the requirements contained in this LIR.
- b. Pressure systems fitting 1-5 above where the system is **behind barricades and/or setbacks**:
- The barricades and setbacks shall be subject to PSC review but not the pressure systems behind them - provided these systems are never pressurized when personnel are inside the barricades and could be exposed to danger.



- The PSC shall be authorized to approve variances to the inclusion criteria above on a case-by-case basis.

### 3. DETERMINATION OF STORED ENERGY

#### a. Gases

**Background:** Gases like air, nitrogen, argon, helium, and hydrogen shall be treated as ideal and the stored energy shall be defined as the free (isentropic) expansion energy down to atmospheric pressure (11.3 psia at 7000 feet elevation). For general interest, this energy is given by

$$E = \frac{p_1 V_1}{k-1} \left[ 1 - \left( \frac{p_2}{p_1} \right)^{\frac{k-1}{k}} \right]$$

where  $p_2 = 77,900$  Pascals (11.3 psia), atmospheric pressure at Los Alamos

$V_1$  is the internal volume of the pressure vessel in cubic meters,

$p_1$  is the MAWP of the pressure vessel in Pascals, and

$k = C_p/C_v$  the ratio of specific heats for an idea gas. For monatomic gases (helium, argon),  $k = 1.66$ . For diatomic gases (air, hydrogen),  $k = 1.4$ . For more complex molecules (carbon dioxide, methane),  $k$  is about 1.3. With the above units,  $E$  is the stored energy in Joules.

**Requirements:** The table below depicts the pressure vessel volumes containing 20 kJ stored energy, above which the requirements contained in this LIR shall apply.

- Although based on air, the table shall apply to all gases.
- It shall be used for the entire *connected* pressure system, obtained by summing the system volumes.
- All pressure systems above 3000 psig shall be subject to the requirements of this LIR.

**Table 1. Pressure System Internal Volumes for Gases for 20 kJ Stored Energy**  
(Linear interpolation is acceptable)

Pressure, psig*	Cubic Inches	Liters	Cubic Feet
5	44000	720	25.4
10	20000	330	11.7
11.3 psia**	17400	285	10.1
15	12500	205	7.24
20	9150	150	5.30
50	2990	49	1.73
100	1340	22	0.780
200	590	9.7	0.343
300	370	6.1	0.215
500	210	3.4	0.120
700	145	2.4	0.085
1000	100	1.6	0.057
1500	60	1.0	0.035
2000	45	0.75	0.026
3000	30	0.48	0.017

\* Maximum operating pressure, including potential fault conditions

\*\* Use for vacuum vessels

**b. Two-Phase Substances****Background:**

- These criteria shall apply to substances that are saturated, that is; liquid and vapor phases coexist at room temperature and elevated pressure. Examples are carbon dioxide, propane and steam.

**Guidance Note:** When these fluids are placed inside a sealed container, changes in temperature produce specific changes in pressure. Adding more fluid to the container increases the fraction of liquid v. gas, but pressure stays the same for the same temperature.

- The stored energy shall be defined as the energy (enthalpy) change during unrestricted (isentropic) expansion from the tank pressure to atmospheric pressure at LANL.
- The table below depicts the masses of carbon dioxide and steam which contain 100 kJ of stored energy, above which the requirements contained in this LIR shall apply for two-phase substances.

**Guidance Note:** Saturated liquid is included because it can also form vapor when expanded to lower pressure.

Commercial propane, LPG, and LNG tanks, coded steam boilers and water heaters, etc. shall be exempt from the requirements contained in this LIR (see list at the end of this Appendix).

**Table 2. Masses of Two-Phase Substances for 100 kJ Stored Energy  
(Linear interpolation is permitted)**

Carbon dioxide - saturated vapor or liquid	1000 grams for either one
Steam - saturated vapor	150 grams for all pressures
Steam - saturated liquid	2200 grams at 200 psia
Steam - saturated liquid	900 grams at 400 psia
Steam - saturated liquid	500 grams at 1000 psia
Steam - saturated liquid	250 grams at 2000 psia

**c. Pressurized Liquids**

**Guidance Note:** Failures of tanks storing pressurized liquids can create very high velocity liquid jets that can penetrate flesh like a bullet and cause so much internal injury that amputation is often necessary. This risk depends on pressure and stored energy. At close range, liquid jets with pressures as low as 100 psig can penetrate the skin. Also, while tanks containing pressurized liquids do not have the blast potential as do vessels with gases, the lack of compressibility makes it is easier to over-pressurize them.

**Requirements:**

- The total stored energy in a pressurized liquid tank shall be the sum of the elastic energy in the liquid and that in the tank.
- The stored energy in the liquid,  $E_{sL}$ , in Joules, is given by

$$E_{sL} = \frac{V_L P_L^2}{2B} ;$$

where  $V_L$  is the volume of liquid in cubic meters,  $P_L$  is the liquid pressure in Pascals (6895 Pa per psi), and  $B$  is the bulk modulus of the liquid, also in Pascals. Some values of  $B$  at room temperature are stated below (Handbook of Chemistry and Physics, 67th ed., pp. F-12-14):

**Table 3. Bulk Modulus for Some Liquids**

Liquid	Bulk Modulus, Pascals
Water	$2.2 \times 10^9$
Acetic acid	$1.1 \times 10^9$
Acetone	$0.8 \times 10^9$
Carbon tetrachloride	$1.0 \times 10^9$
Glycol	$2.7 \times 10^9$
Methanol	$0.8 \times 10^9$
Ethanol	$0.9 \times 10^9$
n-Octane	$0.8 \times 10^9$

- The stored energy in the tank material, in Joules, is given by

$$E_{sT} = \frac{V_T \sigma_T^2}{2E} ;$$

where  $V_T$  is the volume of stressed material in the tank structure in cubic meters, and  $\sigma_T$  is the membrane stress in that material in Pascals.  $E$  is the modulus of elasticity for the material (e.g.,  $1.9 \times 10^{11}$  Pascals for steel).

- The tank cylinder and head stored energies shall be calculated separately and added.

**Guidance Note:** Table 4 shows vessel inside diameters with *water* from 300 to 10,000 psi for 20 kJ total stored energy. The vessel has 2:1 elliptical heads. Three ratios are shown of tank cylinder length to inside diameter. Vessel metal stress is fixed at 15,000 psi. Most metals have ASME allowable stresses of at least this value.

**Table 4. Inside Diameters in Feet for Pressurized Water Tanks Having 20 kJ Total Stored Energy**

Water Pressure, psig	L / D = 3	L / D = 6	L / D = 9
300	4.6	3.9	3.5
500	3.4	2.9	2.6
1000	2.3	2.0	1.8
1500	1.7	1.5	1.4
2000	1.5	1.3	1.2
3000	1.2	1.0	0.90
5000	0.83	0.72	0.65
10000	0.52	0.45	0.41

#### 4. PRESSURE SYSTEMS EXCLUDED FROM THE REQUIREMENTS OF THIS LIR

- A PSC review shall not be required for dynamic experiments covered by the requirements contained in the DOE Explosives Safety Manual (DOE 440.1M) and reviewed by the Explosives Safety Committee, but such pressure safety reviews are recommended.

- The following commercial pressure systems, which have not been modified in any way and which are being used for their intended use, shall be excluded from the requirements contained in this LIR.

**Guidance Note:** However, it is urged that these systems have their own maintenance and inspection procedures.

1. Domestic water systems including sanitary waste systems, and chilled water cooling systems.
2. Fire protection water systems.
3. Natural gas distribution systems (inside and outside)
4. Vehicle systems (engine, hydraulic, and pressurized gas, pneumatic tires)
5. Construction equipment with hydraulic systems, air power hoists, etc.
6. DOT shipping containers including those for HE detonator material.
7. DOT Compressed Gas Cylinders and Containers **except those for nuclear materials.**
8. Commercial containers which contain materials such as spray paint, keyboard cleaners, bug spray, WD-40, molycoat, etc.
9. Systems attached to stationary or mobile equipment that are required for operation and are, in fact, part of the equipment (e.g. diesel generator fuel and cooling systems, automobile fuel), portable or semi-portable cooling and refrigeration systems
10. ASME Section VIII Exempted Vessels:
  - Fire process tubular heaters.
  - Pressure containers that are integral parts or components of rotating or reciprocating mechanical devices, such as pumps, compressors, turbines, generators, engines, and hydraulic or pneumatic cylinders where the primary design considerations and/or stresses are derived from the functional requirements of the device.
  - Structures whose primary function is the transport of fluids from one location to another within a system of which it is an integral part, that is, piping systems.
  - Standard piping components, such as pipe, flanges, bolting, gaskets, valves, expansion joints, fittings, and the pressure-containing parts of other components, such as strainers and devices (which serve such purposes as mixing, separating, snubbing, distributing, and metering or controlling flow) provided that pressure-containing parts of such components are generally recognized as piping components or accessories.
  - Vessels containing nonhazardous liquids under pressure, including those containing cushioning gas, when the pressure is under 300 psig.
  - Hot water supply storage tanks heated by steam or any other indirect means when none of the following limitations is exceeded:
    - (a) a heat input of 200,000Btu/hr,
    - (b) a water temperature of 210° F,
    - (c) a nominal water-containing capacity of 120 gallon,
    - (d) a pressure of 300 psig
11. Propane, LPG, and LNG Coded storage tanks.
12. Commercial HVAC systems.

## APPENDIX 2 (Mandatory)

### VENTING OF FLAMMABLE PRESSURIZED GASES

**Background:** The consequences of venting flammable gases such as hydrogen shall be considered much more severe than venting nitrogen, helium, etc. This Appendix lists special requirements that must be implemented for such gases.

**Guidance Notes:**

- Flammable gases can either ignite with an ignition source (a hot surface or spark), or spontaneously (called "pyrophoric").
- Those requiring an ignition source include hydrogen, propane, butane, propylene, butylenes, carbon monoxide, arsine, disilane, and phosgene.
- Pyrophoric gases include silane, phosphine, and diborane.
- Many of these gases, e.g., phosgene and CO, are also toxic.
- While hydrogen requires an ignition source, its ignition energy in air, only 20 microjoules, is one-tenth that needed to ignite gasoline vapor.
- The flow of the gas can generate many times this static energy; therefore, when designing a hydrogen system, it is prudent to assume the gas is pyrophoric.

**Requirements:** The following requirements must be implemented when pressurized flammable gases are used:

- Minimize inventories.
- Store them safely in a well-ventilated area, preferably outdoors, capped when not in use, and at least 10 feet away from oxidizing gases (except for on dedicated oxygen-acetylene carts).
- Provide a secure electrical ground to all piping, especially vent lines.
- Direct vents, including from pressure relief devices, into approved explosion-proof hoods exhausting above head level or, preferably, outside and above the roof line. Separate vent piping shall be rated to at least 150 psig.
- Assure that the materials used in the system (e.g., in the piping, seals, pumps, and instrumentation), are compatible with the gas.
- Cap off unused, or infrequently used, valve ports. Closing the valve alone is inadequate.
- Place electrical and electronic equipment away from possible flammable gas flows unless they are certified as explosion-proof.
- Have required, readily-accessible, fully-charged fire extinguishers nearby.
- Be familiar with the required emergency procedures.

### APPENDIX 3 (Mandatory)

#### MAXIMUM PRESSURE SYSTEM INSPECTION INTERVALS

##### 1. Background - Selection Of Inspection Intervals

There is a wide range of recommended inspection intervals, but no definitive laws. The pressure system inspection intervals below are based on a combination of recommendations by the API, NBIC, and inspection intervals used by other facilities such as SRS. They have been divided into noncorrosive and corrosive service.

##### 2. Requirements - Maximum Intervals

- The intervals stated below shall be the maximum intervals.
- There shall be no restriction to using shorter intervals if a specific situation warrants it.
- It shall be acceptable (and is sometimes cheaper) to replace a pressure relief device rather than inspect it.

###### a. Noncorrosive Service:

- Pressure relief valves: inspect and pressure test every **5 years**. Replace every **15 years**.
- Rupture discs: inspect every **5 years**. Replace every **15 years**.
- Pressure vessels: external visual inspection every **5 years**, including UT wall thickness spot checks. The UT is to assure it is not actually corroding and can be discontinued once this has been established.
- Piping, valves, gauges and fittings: external inspection every **5 years**.

###### b. Corrosive Service (Including steam, water and possibly moist benign gases. Whether it's corrosive or not depends on the structural material as well as the contents):

- Pressure relief valves: inspect and pressure test every **2 years**. Replace every **15 years**.
- Rupture discs: visually inspect every **2 years**. Replace every **15 years**.
- Pressure vessels: external visual inspection every **2 years**, including dye penetrant weld spot checks and UT wall thickness spot checks. The vessel must be replaced when **less than 2 years** of calculated remaining life is left.

**Guidance Note:** This interval can be increased up to **5 years** once reliable fitness-for-service data is acquired from the inspections. The remaining life can be increased **up to 15 more years** by reducing the maximum operating pressure as required to meet the API 579 Standard for Fitness-for Service.

- Piping, valves, and fittings: external inspection and UT thickness spot checks (where physically possible) every **2 years**. The components must be replaced when **less than 2 years** of calculated remaining life is left.

**Guidance Note:** This interval can also be increased **up to 5 years** once fitness-for-service data is acquired. Also, remaining lifetime can also be increased **up to 10 more years** as in 3 above.

**Guidance Note:** Monthly walk-around visual inspections are highly recommended.

## APPENDIX 4 (Guidance - Not Mandatory)

### PRESSURE SAFETY COMMITTEE REVIEWS

In order to speed up the new pressure system review process by the PSC, the following tasks should be performed beforehand by the pressure system owner. These tasks ensure that the review will be as complete and valuable as possible.

- Thoroughly read and understand this LIR.
- Prepare a Hazard Control Plan for the proposed pressure system that:
  - describes the overall objectives and briefly summarizes the analyses, materials, fabrication methods, and QA with emphasis on unique features of the system that should be brought to the attention of the Pressure Safety Committee. A schematic of the pressure system should be included.
  - identifies the hazards,
  - describes the measures required for mitigating the hazards,
  - identifies training requirements and documents authorization for personnel to operate the pressure system,
  - provides a pressure test plan and inspection/maintenance plan,
  - summarizes the "what-if" exercise used to predict possible failure modes (see Appendix 4 below).
- Review the list of potential failure modes provided in Attachment 4.
- Contact the PSC at 665-6936 or 665-8503.

**Guidance Note:** The PSC should be involved in the entire process of developing the pressure system including design, reviewing the HCP, and inspection the actual system and operating/maintenance procedures.

The purpose of a pressure safety review is to examine the pressure system and ascertain that the pressure safety issues specified in this LIR have been implemented as much as reasonably possible. *The pressure system owner is ultimately responsible for the safety of the system.* It is not possible for members of the PSC to be as knowledgeable as the owner in the complexities and subtleties of the system. Nor can they assure that the system is correctly operated, inspected and maintained. That is the also responsibility of the pressure system owner.

## **APPENDIX 5 (Guidance - Not Mandatory)**

### **LIST OF POSSIBLE PRESSURE SYSTEM FAILURE MODES**

Below is a list of possible failure causes for pressure systems, including those for vacuum and cryogenics. Owners should review for existing pressure systems and designers of new ones. It can serve as a guide for the "what-if" exercise required in the HCP. Note that this list can never be all-inclusive; other failure modes not shown could exist.

- Overconfidence associated with long-term trouble-free operation
- Poor or nonexistent maintenance and inspections
- Inadequate budget (cutting corners)
- Inadequate supervisory oversight
- Operator fatigue, distractions, inattention
- Inadequate safety planning, especially during maintenance or modification
- Unauthorized change in procedures or materials
- Designers and operators had not taken the required general safety training and/or training specific to the pressure system
- Wrong valve(s) opened or closed
- No backflow check valve to prevent cross contamination or overpressurization
- Relief piping directed toward personnel
- Relief piping too small
- Stuck pressure relief system
- Closed valve between pressure vessel and pressure relief system
- Wrong relief device installed
- No relief device on valved-off pumpdown system
- Power outage that can shut off normally-open valves or stop coolant flow
- Warming of cryogen in sealed vessel (e.g., from above)
- Blocked vent (e.g., in above from ice)
- Structural deterioration at fittings and other interfaces
- No pressure regulator, regulator failure, or regulator peak pressure too high (above relief pressure)
- No pressure relief device after pressure regulator
- Unsuitable pressure gauges, piping, valves, instruments and couplings
- Lack of a schematic showing components and their ratings to ensure that proper components are being used
- Flammable material (e.g., oil or carbon) inside oxygen system
- Reheating to room temperature and repressurizing of residual gas in closed vessel after venting
- Coupling disconnected while system is still under some pressure (e.g., due to above)
- Vehicle or other impact (no barriers)
- Chemical corrosion
- End of life exceeded
- Improper material selection (DBTT, temperature, corrosion, etc.)
- No lightning or seismic protection
- Oxygen deficiency due to vented gases



- Subgrade or base failure under large pressure vessel or tank
- Improperly or inadequately analyzed stresses, especially at stress concentrations and view ports
- Unplanned dynamic/explosive event
- High loads during transit caused damage
- Dissimilar materials (joining, differential expansion, galvanic corrosion)
- Brittle materials (e.g., glass windows)
- Direct contact of glass window on metal housing producing stress risers
- Stress corrosion (e.g., chlorides in stressed stainless steel vessel)
- Hydrogen embrittlement, cracking, or blistering
- Steam corrosion (at very high temperatures)
- Cracks in weld and heat-affected zone (usually due to inadequate post-weld heat treatment)
- Unexpected vacuum in vessel designed for pressure (buckling)
- Stored energy of pressure vessel itself not considered
- Retrofit welding caused local weakening of pressure vessel
- Improper gas cover over flammable liquid.

Below is some general information adapted from the National Board

(<http://www.nationalboard.org/Classics/classic9.html>) on why pressure systems fail and what can be done to prevent it:

*Why do pressure vessels fail? In many cases it is a combination of improper operation and poor maintenance. How can we ensure safe operation of these vessels? First and foremost, the vessel must be designed and fabricated in accordance with Section VIII (or III) of the ASME code. After that:*

- 1. The vessel must be properly installed in a suitable area on appropriate foundations with, if necessary, allowance for thermal expansion.*
- 2. The vessel must be properly operated. This is the responsibility of the owners or managers. Their attitude is all important. They are the ones who should ensure that operators are fully trained and re-trained for the job.*
- 3. The vessel must be properly inspected and maintained.*
- 4. The vessel should have the required complement of safety devices.*

*The human element cannot be overlooked in the prevention of accidents. All too often after a long association with an operation, even key operating personnel have a tendency to become careless or lax. Personnel without complete knowledge of the hazards involved in the operation are even more likely to become careless and fail to follow safe operating procedures.*

*A lack of adequate knowledge and understanding is dangerous, especially when working with vessels under high pressure. A very important lesson to be learned from past failures is that just providing properly-constructed equipment will not prevent accidents. Instructions must be understood and employees must be adequately trained if potentially serious accidents are to be prevented. Management should establish definite operating procedures and have them prominently displayed and followed.*

## APPENDIX 6

### (Recommended Guidance - Not Mandatory)

#### **PRESSURE SAFETY WALKAROUND CHECKLIST FOR EXISTING PROGRAMMATIC SYSTEMS**

1. **OPERATOR EXPERIENCE**

Can they describe their system at a level that shows understanding?

Are they alert to pressure system hazards?

Have they had the proper pressure safety training?

2. **OPERATING INSTRUCTIONS**

Readily accessible and used?

Piping and flow diagrams nearby?

3. **PERSONNEL PROTECTION**

Safety glasses and face shields in use?

Gloves used for hot or cold surfaces?

Lexan shields used for intercepting possible fragments?

Buddy system needed and in effect?

4. **SYSTEM CONTENTS**

Toxic, corrosive, flammable, potentially explosive?

If any of these, required labels and required additional safeguards in place?

Ventilation OK?

5. **PRESSURE RELIEF DEVICES**

Are there any?

Located near pressurized sources, including gas bottles?

Any valve between them and pressure source (if so, should be wired and tagged open)?

Vented away from personnel?

Are set pressures high enough to prevent inadvertent venting?

Inspected recently?

6. **PRESSURE VESSELS**

Had Pressure Safety Committee review?

ASME Code stamped?

Protected from impact/damage/abrasion?

Any sign of corrosion, leaks, dents, deep scratches, or support failure?

Inspected recently?

7. **VALVES**

Proper pressure rating?

Open/closed positions readily apparent?

Labels in place showing any critical opening/closing sequences?

Vents directed away from personnel?

8. **PRESSURE GAUGES**

Max reading about twice normal operating pressure?

Shatter-proof face or Lexan shield?

Blowout back plate (for > 100 psi)?  
Digital readouts properly calibrated?

9. **PIPING/HOSES**

Required pressure rating?  
Secured to prevent whipping?  
Protected from impact/damage/abrasion?  
Neat, easily-followed layout?  
Contents and flow directions indicated?  
Any sign of corrosion or leaks?

10. **COMPRESSED GAS BOTTLES**

Correctly secured?  
Regulator condition look OK?  
Fitting/nuts properly tightened?  
Capped if not in use?  
Required separation based on contents?  
Inventory minimized?  
Empties returned to Gas Plant?

11. **DOCUMENTATION**

Drawings, schematics, HCPs, analyses, reviews, memos, approvals available?

12. **PAST HISTORY**

Any history of previous problems/emergencies?

13. **ALARMS**

Readily accessible and working?  
Do operators have familiarity with them?  
Any periodic emergency drills?  
Procedure in place for loss of electricity?

## APPENDIX 7 (Nonmandatory)

### USEFUL REFERENCES

This list of references is for informational purposes only and will be updated only when this LIR is revised.

API Standard 510, 572, 573 - Pressure Vessel Inspection.

API Standards 520, 521, 576 - Pressure Relief Devices.

API Standard 570, 574 - Piping.

API Standard 579 - Fitness for Service.

API 580, 581 - Risk-Based Inspection.

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ANSI/AWS. "Structural Welding Code," ANSI/AWS D 1.1, most recent edition,  
<http://www.lanl.gov/labview/>.

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SRS Engineering Standards Manual, "Pressure Equipment Protection Requirements", WSRC-TM-95-1, 6/6/02.

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Williamson, K. D., and F. J. Edeskuty 1983. Liquid Cryogenics, Vols. I and II, CRC Press, Boca Raton, Florida.

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